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Testing fine sediment connectivity hypotheses using fallout radionuclide tracers in a small catchment with badlands. Vallcebre Research Catchments (NE Spain)

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In the Vallcebre Research Catchments (NE Spain), results obtained during over 20 years showed that badlands are the primary sources of sediments to the drainage network. Parent lutitic rocks are weathered during winter producing regoliths, which are eroded from badland surfaces mainly during summer intense rainstorms. Even if the produced sediments are mainly fine, due to the ephemeral nature of summer runoff events most of them are deposited on the stream beds, where they may remain during some time (months to years).
Within the MEDhyCON project, a fallout radionuclides (FRNs) tracing experiment (i.e. excess lead 210 (Pbx-210) and beryllium 7 (Be-7)) is being carried out in order to investigate sediment connectivity. A simplified Pbx-210 balance model on badland surfaces suggested a seasonal sawtooth-like activity pattern: FRN being accumulated in regoliths from October to June and depleted in summer. Early summer erosion events would produce the sediments with the highest activity whereas late summer events would produce sediments with the lowest activity coming from the deeper regolith horizons.
These findings lead us to launch two sediment transfer connectivity hypotheses analysing respectively the temporal and spatial variability of the Pb-210 activities within the fine sediments at the small catchment scale:
(1) The temporal variability of suspended sediment activities at the gauging stations is a measure of sediment transfer immediacy, ergo connectivity. Hence, a high variability in suspended sediment activities, mimicking regolith activity temporal pattern would indicate high connectivity, whereas a low variability, meaning that sediments are mostly pooled in a large and slowly moving stock, would indicate low connectivity.
(2) In a drainage system where fine sediments temporarily remain on the dry stream bed, the ratio between fine sediment activities at the sources and fine in-stream sediment activities downstream is a measure of sediment connectivity. Indeed, long residence time of stream bed sediments allowing FRN accumulation is suggested by (i) fine in-stream sediment activities higher than those measured at their sources and (ii) increasing activities downstream.
Results showed a more intricate behaviour than expected. Pbx-210 activities of fine bed and suspended sediments were usually below detectable levels or had large uncertainty bounds, confirming that they come mainly from fresh rocks but making difficult the hypotheses testing. Fine sediments on the stream beds had low activities in contradiction with hypothesis 2. Activities of in-stream suspended sediments partly followed hypothesis 1 but they decreased with the increasing capacity of runoff events to mobilise low-activity sediments from the stream bed. Shorter-lived Be-7 activity was detectable only on badland regoliths and suspended sediments, with activities increasing downstream; this cannot be attributed to the accumulation of FRN in old sediments, because of the short life of Be-7. Instead, fine bed sediments might be brought into suspension by raindrop impacts, and most of the FRN content of these raindrops would be flushed with the suspended sediment, impeding its accumulation on bed sediments and disabling hypothesis 2. Overall, several lines of evidence suggest that FRNs were quickly sequestered by the more dynamic sediment particles, preventing its accumulation on coarser sediment particles and surfaces exposed to overland or stream flow.